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OF PHYSICS AND ASTRONOMY R R ANDERSON ET AL 27 JAN 88

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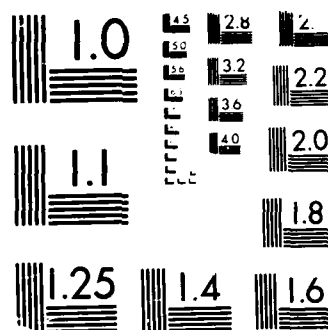
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Final Technical Report for ONR Contract N00014-82-K-0183,  
"A Plasma Wave Instrument on the AMPTE/IRM Spacecraft"

Submitted by

The University of Iowa  
Department of Physics and Astronomy  
Iowa City, Iowa 52242

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19 ABSTRACT (Continue on reverse if necessary and identify by block number) This report summarizes the participation by the University of Iowa in the <u>Active Magnetospheric Particle Tracing Explorers</u> (AMPTE) IRM Plasma Wave Experiment which was funded by ONR. Included are the descriptions of the purposes of the program, the hardware provided, and the data analysis efforts.					
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Final Technical Report1.0 General

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*Roger R. Anderson*

Roger R. Anderson  
Research Scientist

Approved by:

*Donald A. Gurnett*

Donald A. Gurnett  
Principal Investigator

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## 1.0 Introduction

The primary purposes of the Active Magnetospheric Particle Tracing Explorers (AMPTE) program were (1) to carry out the release and monitoring of lithium and barium ions in the solar wind and the distant magnetosphere in order to study the transport and energization of magnetospheric particles, and to investigate the instabilities and wave-particle interactions associated with the releases and subsequent evolution of the injected clouds, and (2) to carry out large releases of barium in the solar wind with the objective of producing artificial comets and studying the interaction of the injected plasma clouds with the solar wind. A complete description of the AMPTE program is contained in the November 9, 1982, volume of EOS, Transactions of the American Geophysical Union, Vol. 63, No. 45, pages 843-850. Complete descriptions of the three spacecraft involved in the AMPTE program, the Charge Composition Explorer (CCE), the Ion Release Module (IRM), and the United Kingdom Subsatellite (UKS) and the experiments on the spacecraft are included in the May 1985 issue of IEEE Transactions on Geoscience and Remote Sensing, Vol. GE-23.

The AMPTE program was a collaborative effort involving the United States, the Federal Republic of Germany, and the United Kingdom. Gerhard Haerendel of the Max-Planck-Institut fur Extraterrestrische Physik (MPE) in Garching bei Munchen, West Germany, principal investigator for the IRM, invited Professor D. A. Gurnett and R. R. Anderson from the University of Iowa to be co-investigators on the IRM plasma wave team. A proposal for the University of Iowa's participation in the AMPTE project

was submitted to the Office of Naval Research and subsequently funded under contract N00014-82-K-0183.

### 3.0 Summary of Work Accomplished

A block diagram of the University of Iowa AMPTE/IRM Plasma Wave Experiment instrumentation is shown in Figure 1. The University of Iowa under this contract provided all of the hardware indicated in the block diagram except for the Fairchild Antenna. The hardware provided by the University of Iowa included the following:

1. One modified spare instrument previously built for the HELIOS Mission, including ground support equipment. The HELIOS Receiver consisted of a 16-channel spectrum analyzer with Peak, Average, and Shock (short time constant) outputs covering the frequency range from 31 Hz to 178 kHz and an Antenna Potential system.
2. One instrument developed for AMPTE consisting of a High Frequency Receiver (100 kHz to 5.6 MHz in 42 steps), a Wideband Analog Receiver (0 to 10 kHz with Automatic Gain Control), and a Power Supply plus ground support equipment for this instrument.
3. A preamplifier housing containing preamplifiers for both instruments listed above and the antenna control electronics.

For approximately the first two and a half years of this contract we designed and constructed the new instrumentation, modified the HELIOS spare instrument for use on AMPTE, and tested and calibrated all of the University of Iowa AMPTE/IRM Plasma Wave Experiment instrumentation. A detailed description of the instrumentation is included in the article "The Plasma Wave Instrument Onboard the AMPTE-IRM Satellite" by Haeusler et al.

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## UNIVERSITY OF IOWA AMPTE IRM PLASMA WAVE EXPERIMENT

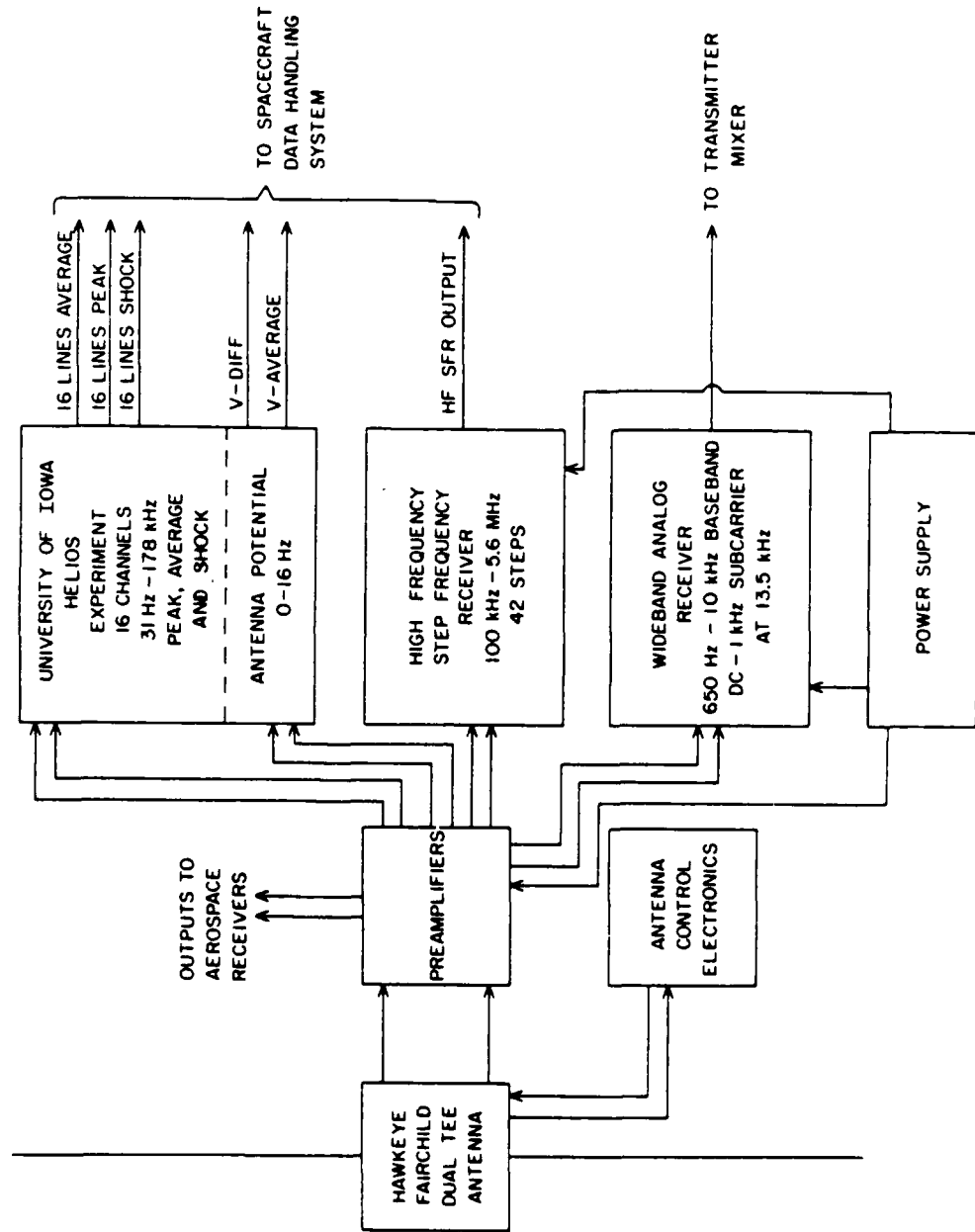


Figure 1

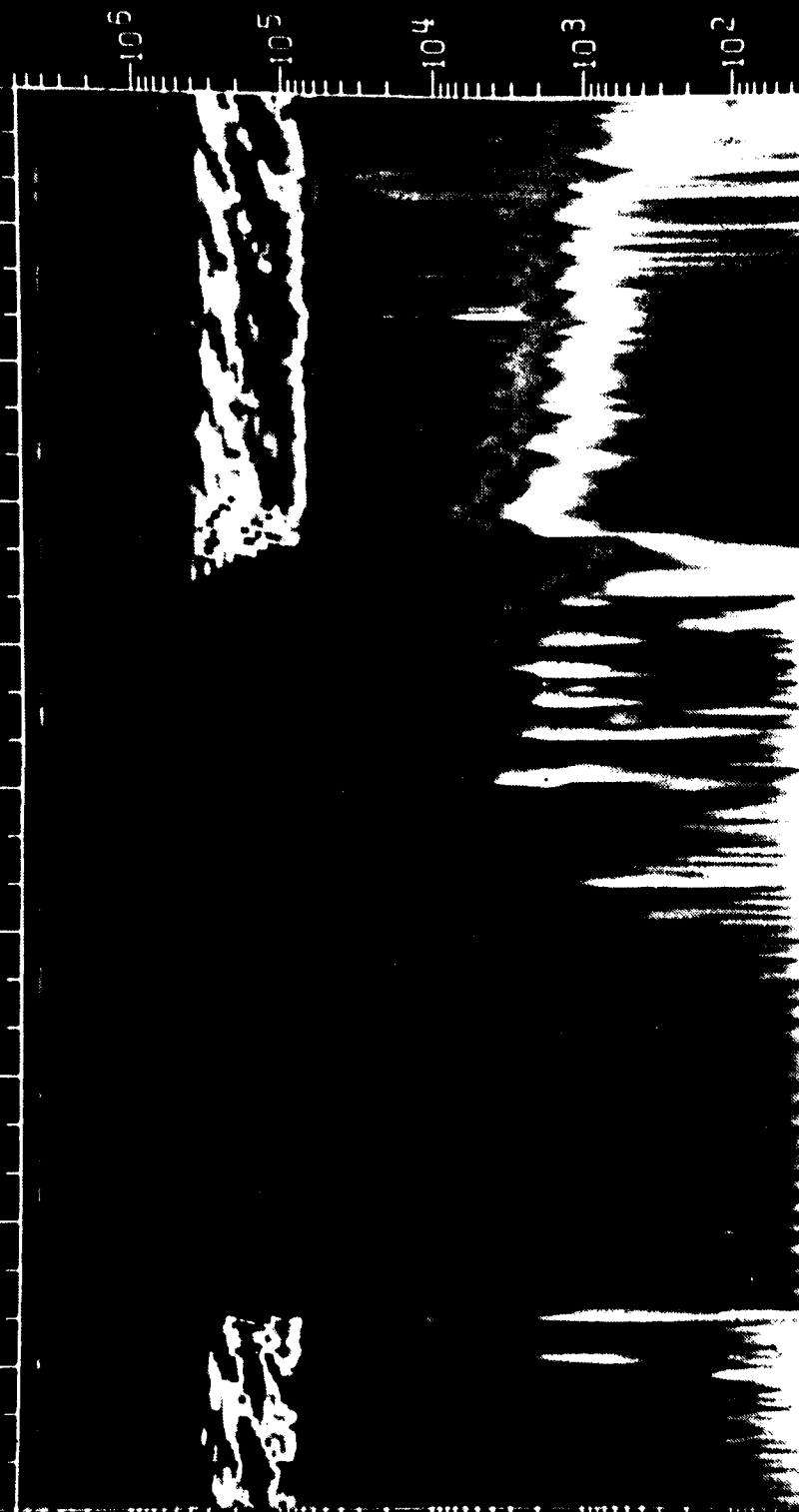


in the May 1985 issue of IEEE Transactions on Geoscience and Remote Sensing, Vol. GE-23, beginning on page 267. The AMPTE spacecraft were successfully launched on August 16, 1984, from Kennedy Space Center in Florida on a Delta launch vehicle. The University of Iowa hardware on the IRM was turned on and the antennas were deployed on August 19, 1984. The instrumentation was checked out and normal operation confirmed.

As part of the data analysis effort, the University of Iowa personnel developed numerous computer programs required for the reduction, analysis, and display of the AMPTE/IRM Plasma Wave Experiment data. This effort began a few months before launch and new programs continued to be developed as needed throughout the remainder of the contract. An especially useful set of programs developed for AMPTE produced composite color spectrograms which displayed the data from the three electric field receivers (the University of Iowa High Frequency Receiver and HELIOS Spectrum Analyzer and the Aerospace/University of Washington Sweep Frequency Receiver) and covered the frequency range from 30 Hz to 5.6 MHz. An example of this type of spectrogram is shown in Figure 2. These spectrograms provided detailed graphic illustrations of the wide variety of plasma wave phenomena associated with the releases. Throughout the period of the contract, University of Iowa personnel participated in AMPTE Science Working Group meetings and AMPTE-IRM Plasma Wave Team meetings to help plan continuing AMPTE operations for the spacecraft, the ground data handling system, and the release operations and to discuss the scientific results.

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Following the launch of AMPTE, the majority of the effort at the University of Iowa under this contract was directed toward studies of wave-particle interactions associated with the ion releases. In September 1984, University of Iowa personnel participated in the AMPTE solar wind lithium release operations at MPE and at the German Space Operations Center (GSOC) where AMPTE/IRM was monitored and controlled. Analysis of the data from the AMPTE/IRM Plasma Wave Experiment was used to help characterize the conditions in the solar wind prior to the releases. Two solar wind lithium releases were carried out, one on September 11, 1984, and a second on September 20, 1984. Data from the University of Iowa Plasma Wave Experiment instrumentation provided the first indications that the releases were successfully accomplished. An abrupt pulse of low frequency electrostatic noise followed by a sudden decrease in amplitudes at almost all frequencies were observed. Inside the diamagnetic cavity created by the release, emissions believed to be associated with the lithium ion plasma frequency were observed. A large variety of plasma wave turbulence was observed for several minutes after the releases. Both electrostatic and electromagnetic waves were generated in the disturbed period as the magnetic field strongly returned and fluctuated. Extremely intense electrostatic waves similar to those observed at the Earth's bow shock were observed when the lithium number density dropped to near the ambient solar wind ion number density. Plasma wave observations during the releases provided useful and detailed measurements of the electron number density in the ion cloud. The High Frequency Receiver, flown for the first time on AMPTE, produced very useful data across its entire frequency range (100 kHz to 5.6 MHz) from

which the efficiency of the release as well as the time history of the number density could be determined. Wideband Analog Receiver data of excellent quality was also acquired during the releases and was used to identify several different types of instabilities such as ion plasma frequency emissions, chorus, electron cyclotron harmonic emissions, and doppler shifted ion acoustic waves. Although no positive unambiguous indication of detection of release-produced lithium ions was made by the CCE experiments orbiting inside the magnetosphere, the releases were considered extremely successful with regard to the studies of instabilities and wave-particle interactions.

A total of eight AMPTE releases were carried out. Following the two lithium solar wind releases discussed above, the first "Artificial Comet" in space was produced by an AMPTE barium release in the solar wind near the dawn magnetosheath on December 27, 1984. On March 21, 1985, AMPTE performed its first barium release in the Earth's geomagnetic tail. University of Iowa personnel participated in the release operations and real-time monitoring of the plasma wave instabilities stimulated by these barium releases. Two AMPTE lithium releases in the Earth's geomagnetic tail were carried out on April 11 and April 23, 1985. The second AMPTE barium release in the tail occurred on May 13, 1985. The last AMPTE release performed was the second "Artificial Comet" which was released in the dusk magnetosheath on July 18, 1985. The principal characteristics of the plasma wave phenomena observed during the eight releases are summarized below.

A brief low-frequency burst of noise was evident at the edge of the diamagnetic cavity for each of the releases. This noise is believed to

be associated with a current driven instability. Intense broadband electrostatic turbulence was detected during each of the solar wind and magnetosheath releases when the ion density from the release became comparable to the ambient number density. Analysis has shown that this turbulence is probably the result of an ion-beam instability resulting from the solar wind protons flowing through the nearly stationary release ions. While all of the releases contained some low frequency electrostatic turbulence during the diamagnetic cavity phase, it was most intense and clearly identifiable during the barium releases. Low frequency ion acoustic emissions and emissions near the barium plasma frequency were observed during the diamagnetic phase of all of the barium releases. The static electric field detected by the plasma wave experiment during the barium releases in the solar wind and magnetosheath was found to be nearly perpendicular to the solar wind velocity indicating that a substantial fraction of the solar wind electric field is able to penetrate into the diamagnetic cavity. During each of the releases detailed electron number density profiles were determined from the observations of the emissions at the electron plasma frequency. The frequency range of these emissions varied from several MHz at the beginning of the releases down to a few kHz or tens of kHz when the effects of the releases disappeared. Evaluation of the number density profiles at the beginning of the releases has yielded the only direct measurements of the ionization rates. During all of the releases the electron density profiles showed considerable structure. For the solar wind and magnetosheath releases the profiles showed the presence of a region of increased number density on the upstream side of the magnetic

cavities. For the barium releases in the geomagnetic tail, large increases in number density were observed coincident with the return of the magnetic field. A common characteristic of all of the releases was the exclusion of all external electromagnetic radiation below the electron plasma frequency. Additionally, all of the releases showed the exclusion of some radiation even above the local electron plasma frequency indicating the presence of a higher density shell away from the spacecraft's location. Further detailed descriptions and interpretations of the data from the plasma wave experiments during the releases are included in the articles included in the Publications section of this report.

The AMPTE/IRM spacecraft continued operating for more than a year after the last release and during this time data was acquired for approximately one third of each day when the spacecraft was visible to the German receiving station. The AMPTE/IRM spacecraft ceased operation on August 12, 1986. We received all of the digital data acquired from the AMPTE/IRM spacecraft during its lifetime. However, due to the limited amount of data analysis funding available, almost none of this data has been analyzed. We have participated with our other AMPTE colleagues on a limited basis in analyzing some of the non-release data. A few of the articles included in the Publications section of this report are primarily concerned with observations not directly related to the releases but of interest to those who study magnetospheric and solar-terrestrial physics. The data sets acquired from the AMPTE/IRM Plasma Wave, Plasma, and Magnetometer Experiments are extremely useful for studying wave-particle interaction processes in the magnetosphere

even when active experiments were not being carried out. Although the instrumentation on the AMPTE/IRM spacecraft came from a variety of groups and had heritages from a number of diverse spacecraft projects, the resulting experiments provided sophisticated and high quality measurements of the basic parameters required for studying magnetospheric wave-particle interaction processes and boundary phenomena. If additional data reduction and analysis funding were available in the future, comparison of the AMPTE/IRM field and particle measurements with those from the ISEE 1, ISEE 2, AMPTE/UKS, and AMPTE/CCE in studying magnetospheric boundary motions and other magnetospheric processes deserves important consideration.

#### 4.0 Technical Reports

This final technical report is the only technical report submitted under this contract.

#### 5.0 Publications

The following publications involve the AMPTE/IRM Plasma Wave Experiment and the efforts supported by ONR contract N00014-82-K-0183.

1. The Plasma Wave Instrument Onboard the AMPTE-IRM Satellite  
B. HAEUSLER, R. R. ANDERSON, D. A. GURNETT, H. C. KOONS, R. H. HOLZWORTH,  
O. H. BAUER, R. A. TREUMANN, K. GNAIGER, D. ODEM, W. B. HARBRIDGE, AND F.  
EBERL  
IEEE Trans. Geosci. Remote Sensing, GE-23, 267, 1985.
2. Plasma Waves Associated With the AMPTE Artificial Comet  
D. A. GURNETT, R. R. ANDERSON, B. HAEUSLER, G. HAERENDEL, O. H. BAUER,  
R. A. TREUMANN, H. C. KOONS, and R. H. HOLZWORTH, H. LUEHR  
Geophys. Res. Lett., 12, 851, 1985.
3. Electron-Cyclotron Harmonic Waves Excited by a Lithium Release in the  
Solar Wind on AMPTE/IRM  
H. C. KOONS, B. HAEUSLER, R. R. ANDERSON, D. A. GURNETT, R. H. HOLZWORTH,  
O. H. BAUER, R. A. TREUMANN  
J. Geophys. Res., submitted, 1985.

4. Plasma Waves Observed by the IRM and UKS Spacecraft during the AMPTE Solar Wind Lithium Releases: Overview  
B. HAEUSLER, L. J. WOOLLISCROFT, R. R. ANDERSON, D. A. GURNETT, R. H. HOLZWORTH, H. C. KOONS, O. H. BAUER, G. HAERENDEL, R. A. TREUMANN, P. J. CHRISTIANSEN, A. G. DARBYSHIRE, M. P. GOUGH, S. R. JONES, A. J. NORRIS, H. LUHR, AND N. KLOCKER  
J. Geophys. Res., 91, 1283, 1986
5. Analysis and Interpretation of the Shock-Like Electrostatic Noise Observed During the AMPTE Solar Wind Lithium Releases  
D. A. GURNETT, T. Z. MA, R. R. ANDERSON, O. H. BAUER, G. HAERENDEL, B. HAEUSLER, G. PASCHMANN, R. TREUMANN, H. KOONS, R. HOLZWORTH and H. LUEHR  
J. Geophys. Res., 91, 1301, 1986.
6. Plasma Waves Associated With the First AMPTE Magnetotail Barium Release  
D. A. GURNETT, R. R. ANDERSON, P. A. BERNHARDT, H. LUEHR, G. HAERENDEL, O. H. BAUER, H. C. KOONS and R. H. HOLZWORTH  
Geophys. Res. Lett., 13, 644, 1986.
7. Waves and Electric Fields Associated with the First AMPTE Artificial Comet  
D. A. GURNETT, T. Z. MA, R. R. ANDERSON, G. HAERENDEL, G. PASCHMANN, O. H. BAUER, R. A. TREUMANN, H. C. KOONS, R. H. HOLZWORTH, and H. LUEHR  
J. Geophys. Res., 91, 10,013, 1986.
8. Electron Plasma Waves in the Solar Wind: AMPTE/IRM and UKS Observations  
R. A. TREUMANN, O. H. BAUER, J. LABELLE, G. HAERENDEL, P. J. CHRISTIANSEN, A. G. DARBYSHIRE, A. J. NORRIS, L. J. C. WOOLLISCROFT, R. R. ANDERSON, D. A. GURNETT, R. W. HOLZWORTH, H. C. KOONS, and J. ROEDER  
Adv. in Space Res., 6, 93, 1986.
9. Electrostatic Waves Generated by Gases Interfacing with Flowing Plasmas  
TI-ZE MA  
Ph.D. Thesis, The University of Iowa, August 1986.
10. A Comparison of the Plasma Wave Spectra from 100 Hz to 100 kHz for the Eight AMPTE Chemical Releases  
H. C. KOONS, R. R. ANDERSON, O. H. BAUER, D. A. GURNETT, G. HAERENDEL, R. H. HOLZWORTH, J. L. ROEDER, R. TREUMANN  
J. Geophys. Res., submitted, 1986.
11. An Analysis of the Shocklike Electrostatic Noise Observed During AMPTE Solar Wind Ion Releases  
T. Z. MA, D. A. GURNETT, AND N. OMIDI  
J. Geophys. Res., 92, 2555, 1987.
12. Electron Cyclotron Harmonic Waves Observed by the AMPTE-IRM Plasma Wave Experiment Following a Lithium Release in the Solar Wind  
J. L. ROEDER, H. C. KOONS, R. H. HOLZWORTH, R. R. ANDERSON, O. H. BAUER, D. A. GURNETT, G. HAERENDEL, B. HAEUSLER, AND R. TREUMANN  
J. Geophys. Res., 92, 5768, 1987.



13. Observations and Theory of the Ampte Magnetotail Barium Releases  
P. A. BERNHARDT, R. A. ROUSSEL-DUPRE, M. B. PONGRATZ, G. HAERENDEL, A. VALENZUELA, D. A. GURNETT, R. R. ANDERSON  
J. Geophys. Res., 92, 5777, 1987.
14. AMPTE/IRM Observations of Waves Associated with Flux Transfer Events in the Magnetosphere  
J. LABELLE, R. A. TREUMANN, G. HAERENDEL, O. H. BAUER, G. PASCHMANN, W. BAUMJOHANN, H. LÜHR, R. R. ANDERSON, H. C. KOONS, and R. H. HOLZWORTH  
J. Geophys. Res., 92, 5827, 1987.
15. Observation of Nonlinear Wave Decay Processes in the Solar Wind by the AMPTE IRM Plasma Wave Experiment  
H. C. KOONS, J. L. ROEDER, O. H. BAUER, G. HAERENDEL, R. TREUMANN, R. R. ANDERSON, D. A. GURNETT, R. H. HOLZWORTH  
J. Geophys. Res., 92, 5865, 1987.
16. Simulation and Non-Linear Stage of the Electrostatic Waves Observed During the AMPTE Lithium Release in the Solar Wind  
N. OMIDI, T. Z. MA, K. QUEST, M. ASHOUR-ABDALLA, D. GURNETT, R. SYDORA  
Adv. in Space Res., in press, 1987.
17. Electron Number Density from the AMPTE/IRM Plasma Wave Experiment During Solar Wind Lithium Releases  
R. R. ANDERSON, D. A. GURNETT, B. HAEUSLER, H. C. KOONS, R. H. HOLZWORTH, R. A. TREUMANN, O. H. BAUER, G. HAERENDEL, H. LUEHR, L. J. WOOLLISCROFT, AND M. P. GOUGH  
J. Geophys. Res., submitted, 1987
18. Nature and the Nonlinear Evolution of Electrostatic Waves Associated with the AMPTE Solar Wind Releases  
N. OMIDI, K. AKIMOTO, D. A. GURNETT, AND R. R. ANDERSON  
J. Geophys. Res., submitted, 1987.
19. High Frequency Electrostatic Waves at Earth's Bow Shock  
T. G. ONSAGER, R. H. HOLZWORTH, H. C. KOONS, O. H. BAUER, G. HAERENDEL, R. TREUMANN, D. A. GURNETT, R. R. ANDERSON, H. LUEHR, AND C. W. CARLSON  
J. Geophys. Res., submitted, 1987.

## 6.0 Oral Presentations

The following oral presentations involve the AMPTE/IRM Plasma Wave Experiment and the efforts supported by ONR contract N00014-82-K-0183.

1. Electron Number Density from the AMPTE/IRM Plasma Wave Experiment During Solar Wind Lithium and Barium Releases  
R. R. Anderson, D. A. Gurnett, B. Haeusler, R. A. Treumann, O. H. Bauer, G. Haerendel, H. C. Koons, R. H. Holzworth  
1985 Spring AGU Meeting, Baltimore, Maryland, May 27-31, 1985.
2. An Ion Beam-Plasma Instability for Explaining the Electrostatic Noise Associated with the AMPTE Solar Wind Ion Releases  
T. Z. Ma, D. A. Gurnett, R. R. Anderson, O. H. Bauer, G. Haerendel, B. Hausler, G. Paschmann, R. A. Treumann, H. C. Koons, R. H. Holzworth  
1985 Spring AGU Meeting, Baltimore, Maryland, May 27-31, 1985.
3. Electron Cyclotron Harmonmic Waves Observed by the AMPTE-IRM Plasma Wave Experiment Following a Lithium Release in the Solar Wind  
H. C. Koons, J. L. Roeder, O. H. Bauer, B. Hausler, R. A. Treumann, R. R. Anderson, D. A. Gurnett, R. H. Holzworth  
1985 Spring AGU Meeting, Baltimore, Maryland, May 27-31, 1985.
4. Plasma Wave Observations During the AMPTE Lithium and Barium Releases  
D. A. Gurnett, R. R. Anderson, O. H. Bauer, G. Haerendel, B. Haeusler, R. A. Treumann, H. C. Koons, R. H. Holzworth  
1985 Spring AGU Meeting, Baltimore, Maryland, May 27-31, 1985.
5. Interpretation and Analysis of the Electrostatic Noise Associated with Solar Wind Releases  
D. A. Gurnett, T. Z. Ma, R. R. Anderson, O. H. Bauer, G. Haerendel, B. Haeusler, G. Paschmann, R. A. Treumann, H. C. Koons, R. H. Holzworth, H. Luehr  
Prague IAGA Assembly Session 3.8, Prague, Czechoslovakia, August 5-17, 1985.
6. A comparison of the Plasma Wave Spectra from 100 Hz to 100 kHz for the Eight AMPTE Chemical Releases  
H. C. Koons, R. R. Anderson, O. H. Bauer, D. A. Gurnett, G. Haerendel, R. H. Holzworth, J. L. Roeder, R. Treumann  
1986 URSI National Meeting, Boulder, Colorado, January 13-16, 1986.
7. Plasma Wave Comparisons Between the AMPTE Artificial Comet Releases and the Earth's Bow Shock  
T. Onsager, R. Holzworth, D. A. Gurnett, R. R. Anderson, O. H. Bauer, G. Haerendel, H. C. Koons, C. Carlson  
1986 Spring AGU Meeting, Baltimore, Maryland, May 19-23, 1986.
8. Simulation of Electrostatic Waves Generated During the AMPTE Lithium Release in the Solar Wind  
N. Omid, M. Ashour-Abdalla, D. A. Gurnett, R. D. Sydora  
1986 Spring AGU Meeting, Baltimore, Maryland, May 19-23, 1986.

9. Shock-Like Processes Associated with the AMPTE Solar Wind Releases  
D. A. Gurnett  
XXVI COSPAR Meeting, Toulouse, France, June 30-July 12, 1986.
10. Simulation of Electrostatic Waves Generated During the AMPTE Lithium Release of the Solar Wind  
N. M. Omid, T. Z. Ma, M. Ashour-Abdalla, D. A. Gurnett  
XXVI COSPAR Meeting, Toulouse, France, June 30-July 12, 1986.
15. Electron Plasma Waves in the Solar Wind: AMPTE/IRM and UKS Observations  
O. H. Bauer, P. J. Christiansen, J. LaBelle, A. J. Norris,  
R. A. Treumann, L. J. Woolliscroft, R. R. Anderson, H. C. Koons  
XXVI COSPAR, Toulouse, France, June 30-July 12, 1986.
16. Plasma Wave Observations During the AMPTE Barium and Lithium Releases in the Solar Wind, Magnetosheath, and Tail  
R. R. Anderson, D. A. Gurnett, O. H. Bauer, G. Haerendel, G. Haeusler  
R. A. Treumann, R. H., Holzworth, H. C. Koons  
XXVI COSPAR, Toulouse, France, June 30-July 12, 1986.
11. Magnetic Field Dependence of Electrostatic Waves in the Earth's Foreshock and Magnetosheath  
T. Onsager, R. H. Holzworth, H. C. Koons, O. H. Bauer, G. Haerendel,  
R. Treumann, D. A. Gurnett, R. R. Anderson, H. Luhr  
1986 Fall AGU Meeting, San Francisco, California, December 8-12, 1986.
12. AMPTE/IRM Traversals of the Plasmopause and the Inner Edge of the Ring Current  
J. LaBelle, G. Haerendel, R. A. Treumann, W. Baumjohann, O. H. Bauer,  
G. Paschmann, N. Sckopke, R. R. Anderson, D. A. Gurnett, H. C. Koons,  
R. Holzworth, H. Luehr  
1986 Fall AGU Meeting, San Francisco, California, December 8-12, 1986.
13. A Survey of Impulsive Broadband Electrostatic Waves in the Magnetosphere  
J. L. Roeder, H. C. Koons, O. H. Bauer, G. Haerendel, R. Treumann,  
R. R. Anderson, D. A. Gurnett, R. H. Holzworth  
1986 Fall AGU Meeting, San Francisco, California, December 8-12, 1986.
14. Plasma Wave Observations Associated with the AMPTE Ion Releases  
R. R. Anderson, D. A. Gurnett, G. Haerendel, O. H. Bauer, B. Haeusler,  
R. A. Treumann, H. C. Koons, R. H. Holzworth  
Kyoto Workshop on Active Experiments, Kyoto, Japan, October 18-22, 1987.

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